Collaborative Engineering with Interactive Displays

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Abstract: This paper deals with the usage of the fundamental technology that realizes the interaction with interactive displays to support collaborative work. The system allows to interact with touchevents or to take notes and drawing during a meeting.
However, a rising popularity of devices which are based on multi-touch technology can be noted. These technologies do not deliver solutions of supporting collaborative work in the industry and especially not in the engineering context.
Therefore we present a collaborative concept to support collaborative work in engineering environments using interactive display technologies. We provide an introduction of the approaches that support collaborative work through these technologies. These will facilitate faster development in this context. The results of the evaluation show how professionals in the open industry would assess the concept. We can conclude that the majority of the participants prefer the utility of the introduced concept regarding the facilitation of collaborative work.

1. Introduction

The human computer interface is continuously improving and users permanently get new possibilities to enter specific data to the digital system. The keyboard as well as the computer mouse are still reliable input devices and are still efficient for certain fields of application. However, in a lot of different situations we have the preference to make *handwritten* notes, sketches or drawings directly on the computer. The users can use the computer mouse or a track pad to make drawings directly on the computer and therefore solve the problem rudimentarily. However, the usage of these input devices to make handwritten notes or sketches is not very intuitive.

While observing scenarios of collaborative work, one can recognize that handwritten notes or sketches are used very often in the context of meetings or conferences. Thereby traditional black boards, paper notebooks or regular white boards are usual tools. A reason for using these traditional tools is given through their reliability. Users can trust on the traditional pen and paper techniques. The possibility of losing data by working with pen and paper is considerably less than using computer systems. Additionally, users are used to traditional pen and paper and therefore they do not need to get used to new digital computer technology.
Today, however, most companies' data is required digitally. Specific sketches or reports for example have to be sent to employees who are based in other countries or cities. Applying the traditional pen and paper techniques, we need to digitalize for instance the results of a meeting. This process is not efficient and is thus time-consuming for the employees. Another situation in wich analogue sketches are problematic and not efficient is the context of engineering meetings. Engineers usually have a few technical drawings they discuss during a meeting. The plans are mostly printed on paper or displayed on large displays. The additional drawings are made by the participants on paper or special programs which the engineers are using. The changes on the technical plan, made during the meeting, have to be digitalized afterwards through a CAD

(Computer Aided Design) software application. Through these examples we can see that transferring handwritten documents into digital form is undesired.
With the now existing digital pen technologies like tablet PCs, it is possible to save handwritten data digitally on the tablet PC. Nevertheless, this technology cannot support collaborative work because participants are not able to work simultaneously on this computer system. On the other hand we can see the rising popularity of multi-touch systems [1]. Large multi-touch solutions like the Microsoft Surface [2] could support collaborative work through the possibility of using the table sized surface with other participants of the meeting simultaneously. With this solution the participants can sit or stand around the table and have a similar working desk like the traditional writing desk.
The usage of the multi-touch and Anoto technology combines the traditional world with digital fields. Paper-based interaction can be realized and therefore we can receive handwritten data on digital computer applications. But the technologies themselves are not enough to support collaborative work in the open industry. We need a *concept* that uses these technologies and couples the workflow of employees with the digital systems.

This paper deals with the facilitation of collaborative work. As an example to illustrate the facilitation we focused on the engineering domain. We received requirements from engineers according to our custom-made digital system that should be implemented to support collaborative work in the engineering domain. The list of requirements included that the system should make it possible for the user to change digital content dynamically. We also figured out through the requirements that the digital computer system should distinguish between the different users interacting with the software. Additionally, the users should have a private working area. The security of the digital system is also an important requirement for engineers.
Our aim is to support collaborative work through our *collaborative concept*. After giving an overview about the related research projects, we first introduce the current technologies that were used to realize our custom-made software. Through the approach to support collaborative work with our software in the engineering context we want to show that the workflow in general business environments can be supported. We will present a solution that makes the used interactive displays in combination with new pen technology more accessible by other companies through porting the technology. Hence we made an evaluation and asked experienced engineer professionals about our system and concept. In summary, we combined three approaches in this paper to support collaborative work: (i) using interactive displays (ii) using the Anoto technology(iii). Because of the technical focus of approach we do not include this approach in the evaluation. At the end of this paper we give a conclusion and outline our future work.

2. Related Work

Haller et al. [3] developed an interactive room to support collaborative work. The digital conference room used interactive displays including a digital whiteboard and multi – touch technology. To include traditional paper scratches they combining paper based interaction through the Anoto technology. Empirical results, which indicate that the use of this digital conference room supports collaborative work, are shown in that paper. Also the facts of the paper show that the system based on these technologies is intuitive to use. However, we can see that their solution is not focusing on a specific domain or the facilitation of collaborative work in the open industry.
Brandl et al. [4] combine the paper-based world with digital systems. They focus on interactive paper and resolve the issue to integrate real paper in digital environments. Their conclusion reflects that real paper is still needed and necessary for many working fields.
Paper-based interaction is also examined by Liao et al. [5]. They describe how users can take real printouts as a proxy to change digital data. Staying with real paper, Yeh et al. [6] outline the use of interactive paper to combine handwritten notes and pictures to one document on computer systems. The project tries to support biologists in fieldwork.

Scott et al. [7] cover the usage of the Anoto and multi-touch technology to support collaborative work in military environments. By facilitating collaborative work they want to achieve faster decision-making and a faster workflow. Therefore they developed design requirements, which should be considered by developing multi-touch applications for military contexts. By presenting a custom-made software prototype to military personnel, the authors received positive feedback.

Interactive Tabletop Displays

Multi-touch tabletops have like the current smartphones a touch surface for multiple finger inputs. Most tabletops have the advantage that they provide a large surface. So they are predestined to support collaborative work of many people. One of the first tabletops was the Diamond Touch. The speciality of the Diamond Touch is its ability to identify the user explicitly [8]. Further optical techniques are developed to offer even more possibilities of interaction. Now there are a lot of techniques to realize optical multi-touch tabletops. All these techniques use infrared light to detect fingerprints. In or around the table are several infrared-strips to illuminate the surface. When an object or finger touches the surface, it reflects at this point more than the surface reflection. An infrared camera is then able to detect these points. In the table also a computer is installed to interpret these data with software. The different technologies provide various possibilities. Jefferson Y. Han is one of the main developers of the optical multi-touch tabletops and he developed the FTIR-technique [9]. The FTIR-technique (Frustrated Total Internal Reflection) allows to use optical tabletops stable on daylight. These innovative optical techniques allow tangibles [10]. Tangibles are objects that can be placed on the tabletop. They are badges that are pasted under an object. The camera is able to see these badges and identify the tangibles. To use tangibles, it is necessary to work with the DI (Diffused Illumination) or DSI-technique (Diffused Surface Illumination). The Microsoft surface used these technologies for instance. A multi-touch table is able to recognize various tangibles, the position and the orientation of a tangible. Tangibles enable a deeper and more intuitive usage of touchscreens because of the additional user input and the explicit identification of tangibles.

The Anoto Technology

The Swedish company *Anoto* developed a technology for tracking positions of digital pens on a specific pattern [11, 12]. This technology realizes the interaction between real paper and digital realms.

Fundament of the technology is a dot-pattern which has to be printed on the interaction surface. The pattern consists of black carbon dots. Apart from the required dot pattern, a digital Anoto pen is necessary for the interaction with a digital computer system. An infrared camera and an infrared LED are installed in the pen's tip.

While the user writes with the pen on the patterned surface, the infrared LED is being activated. The patterned surface reflects the light while the black carbon dots on the surface absorb the IR-light. Consequently the IR camera detects the surface as a very bright background and the dots are seen dark by the camera at the same time. A combination of different points detected on the pattern makes it possible for the Anoto pen to recognize its unique position on the surface. This information can be sent via Bluetooth or USB docking station to a computer system. By using the Bluetooth technology, the streaming of the pens data to the computer is possible in real time. To realize an interaction between real *paper* and a computer system, the dot pattern has to be printed on the paper. Additionally, the digital pens can be used for instance on a multi-touch surface with an overlaid Anoto pattern.

The information received by the digital computer system, such as a multi-touch table, can reconstruct the written information or work with the pens‘ coordinates. This can be useful for example to realize pressing digital buttons on the digital surface.

3. Technical System to Support Collaborative Work

Sharing and distributing information is in the process of planning in engineering a highly significant aspect. Using the previously mentioned technologies to facilitate the workflow in working groups with the goal to support collaborative work is shown for instance in engineering projects.
Therefore we developed a hardware prototype for the context of engineering. Engineers can work together on one construction plan on a multi-touch table. The users are able to interact on the interactive surface in any angle. Further more the participants can also work simultaneously through an independent work area for each person. Therefore this area containing information is managed in a window that can easily be moved by the person's finger-input.

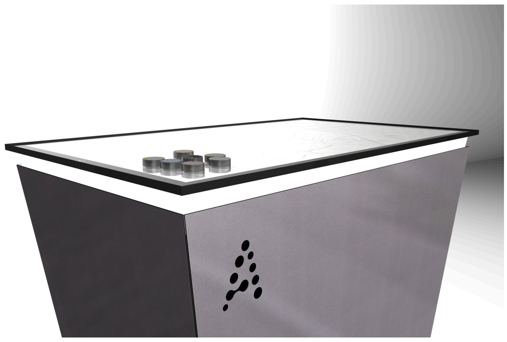

Figure 1: The hardware prototype.

Additionally, using digital Anoto pens for each person facilitates drawing on the projected technical drawing with various toolkits like stroke sizes and colors. The Anoto-technology also allows digital pens to be used on traditional paper with a regular pen tip. Thus, the participants are able to send drawings taken during the meeting from real paper to the multi-touch table for presentation purposes [4]. Furthermore, the architects are able to store the plan with the additional drawings digitally. In this way it is possible to duplicate the information and to send them to all participants of the meeting or workshop. The results of the meeting can be presented later on a wall through a projector. After discussions about the technical implementation it is possible to return to old versions of the plan's digital history.
In the process of planning or during discussions it is often necessary that the system can distinguish between the users. It is useful to give for instance more permission for the system and more access for the software functions to a project manager than to regular participants. In this way, the project manager could be able to change a specific content on the system to a persistent status whereas the other users do not have any permission to change the data. Beyond that, it might be helpful to know who added which information and most specifically, at which time. The so-called *logging of users* makes it possible to assign the information to the specific participant. To resolve these issues, we used the unique Anoto identity number, which is being sent from the Anoto-pen to the computer system via Bluetooth. In this way the system records which user interacts with the interface. On the multitouch way we get a personal identifikation by depth detection. There all the users where filmed by a special depthdedection camera to identify all the users around the table. To make this system more secure for more critical context with extremely sensitive data, we implemented a multi-authorization. This indicates that each person has to be authenticated by a password or more desirable by biometric scans.
Figure 1 a hardware prototype, running on a DSI multi-touch table, and a user interacting with an Anoto pen. The software is written in the object orientated programming language JAVA. To receive the pen data in real time at the .NET application we used the custom-made *application-programming interface (API)* developed by Haller et al. [11].

4. Evaluation of the Technical Concept

After the development of the introduced approaches to support collaborative work, we want to assess whether professionals in the industry, who have experience in the engineering environment, will accept our concept. Moreover we wanted to receive the opinion of these professionals to identify our weak spots and the positive aspects of our system that could facilitate the workflow in engineering office.

Therefore we presented our concept to engineer professionals who are experienced in the field of information technology. One the one hand we select people who are professionals in designing hardware. On the other hand we choose experts in designing software. David Amend a student at the university of applied science and arts in Dortmund, recorded the complete meeting for later reviewing. Additionly he prepares a special questioner to look how the people are working together in a meeting. One of the questions was about the usage of actual display technologies. We present two of the questions to understand why it is so important to support collaborative work in the engineering context.

“How do you present a displayconent on device if more then one user exists?” – The answer was: “ We pass the device around”. Another question was: “ What reworking of the meeting is for the treatment of the content necessary?”- The answer was “We take photos of all the written content at the whiteboard”. This situation shows how the various people are actual working in the engineering context.

After the questions about the actual situation we present our system to evaluate how and whether the system supports collaborative work. The presentation of our concept took place at the engineering office where the participants work. After the presentation, a discussion started through the interest and questions of the engineers.
To our satisfaction, the audience was interested in more details about the interactive display technology. They identified an added value and they surveyed can imagine working with the developed system in future.

5. Results and Conclusion

All in all the technical possibilities are very interesting in this context. Additionally we see the rising popularity of interactive display systems. The multi-touch and pen-based technology supports an intuitive interaction of computer systems for collaborative working.
Therefore we decided to elaborate a concept and to evaluate it based on our dedicated prototype. We presented our hardware prototype that should support collaborative work in the engineering domain. In contrast to most related works, we did not have the aim to support collaborative work just by developing user-friendly computer interfaces. We elaborated our concept from the viewpoint of the companies and thus figured out that costs are a major concern regarding technical products.
We developed a cheap hardware-prototype with a non-commercial software. Thus, the companies do not need to invest a lot of financial sums through hardware and software solutions and have the possibility to get a better workflow in the business domain.

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